Optical Pumping

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Overview

- Introduction/Background
  - Optical Pumping
  - Mercury Arc Light
- Tests and Data
  - Proof-of-concept
  - To Failure
  - AFRL parts
- Future Work

INTRODUCTION

- Limitations of high temperature accelerated testing
- Understanding non-temperature acceleration factors
- More realistic MTTF

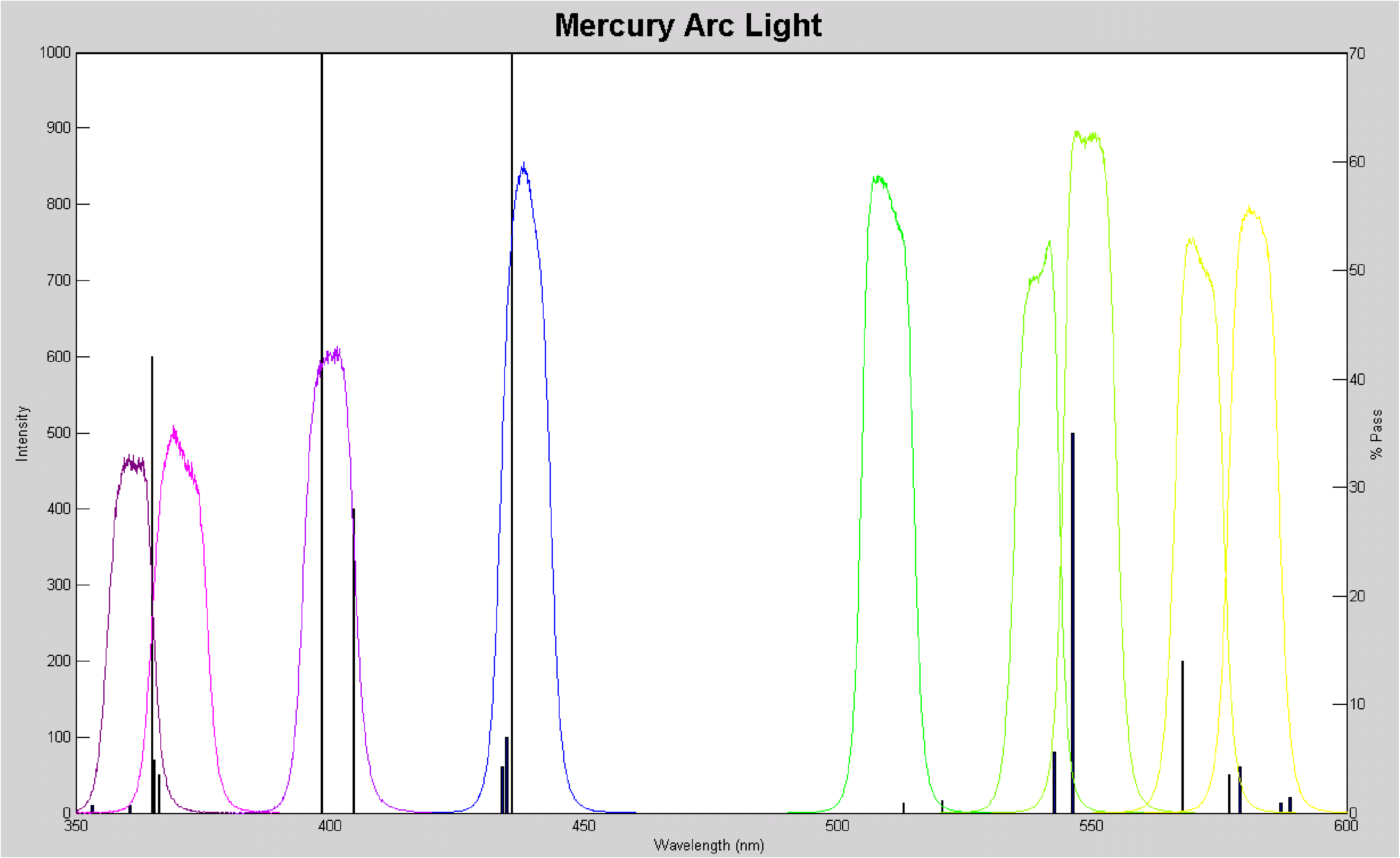
Background

- Accelerate aging by optically pumping a GaN HEMT under DC bias stress
- Unfiltered mercury arc light source
  - Pumps above-band-gap energy into the device
  - Emptying all the traps within the band-gap
  - Exciting electrons into the conduction band
- Filtered Light
  - Below band-gap to target specific traps

BACKGROUND

- Optical pumping results in increased I_D
  - Excited electrons from the valence band
  - Emptied traps
- Increased I_D
  - Test the effects of drain currents under lower drain-source fields
  - Reach higher power levels with lower gate-drain fields
  - Targets the device's channel

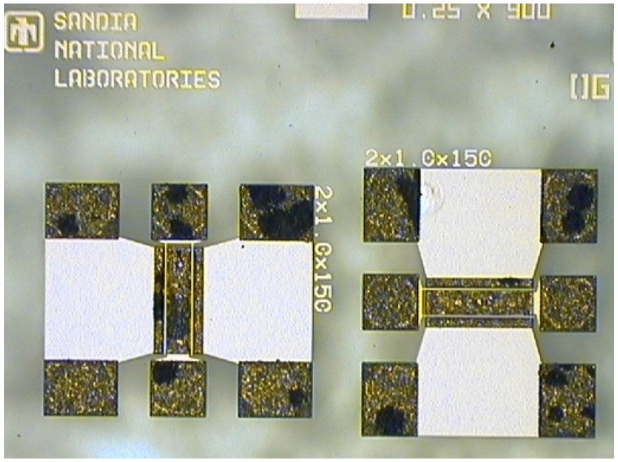
BACKGROUND



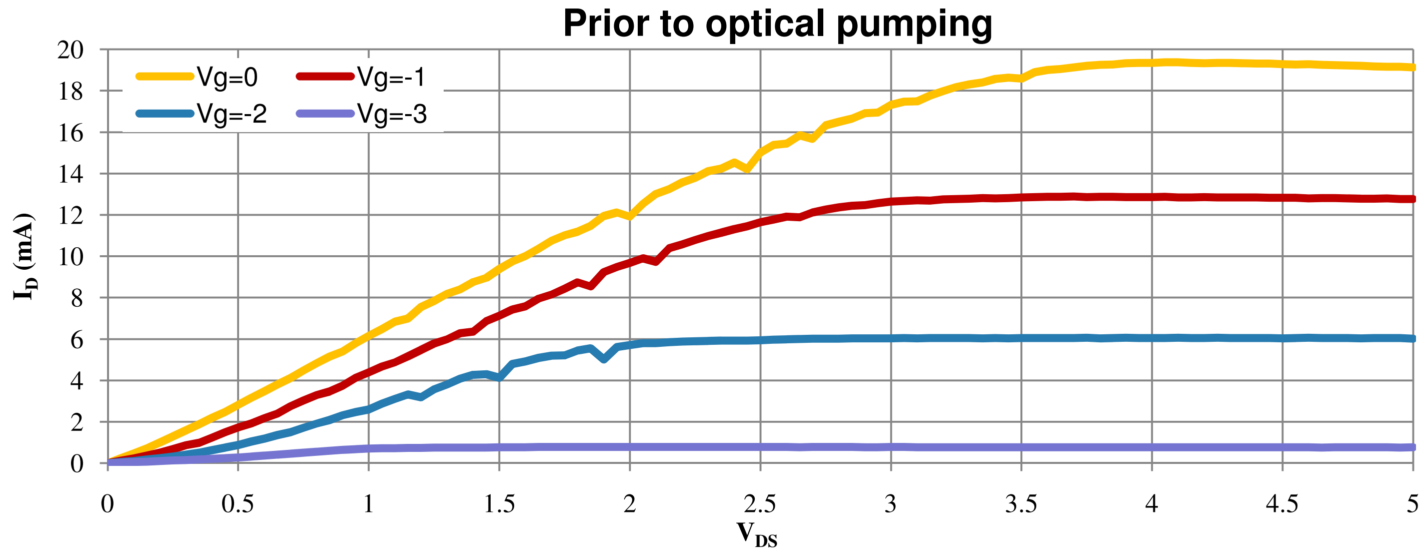
Mercury Arc Light
Intensity
% Pass
Wavelength (nm)
0
100
200
300
400
500
600
700
800
900
1000
350
400
450
500
550
600
0
10
20
30
40
50
60
70

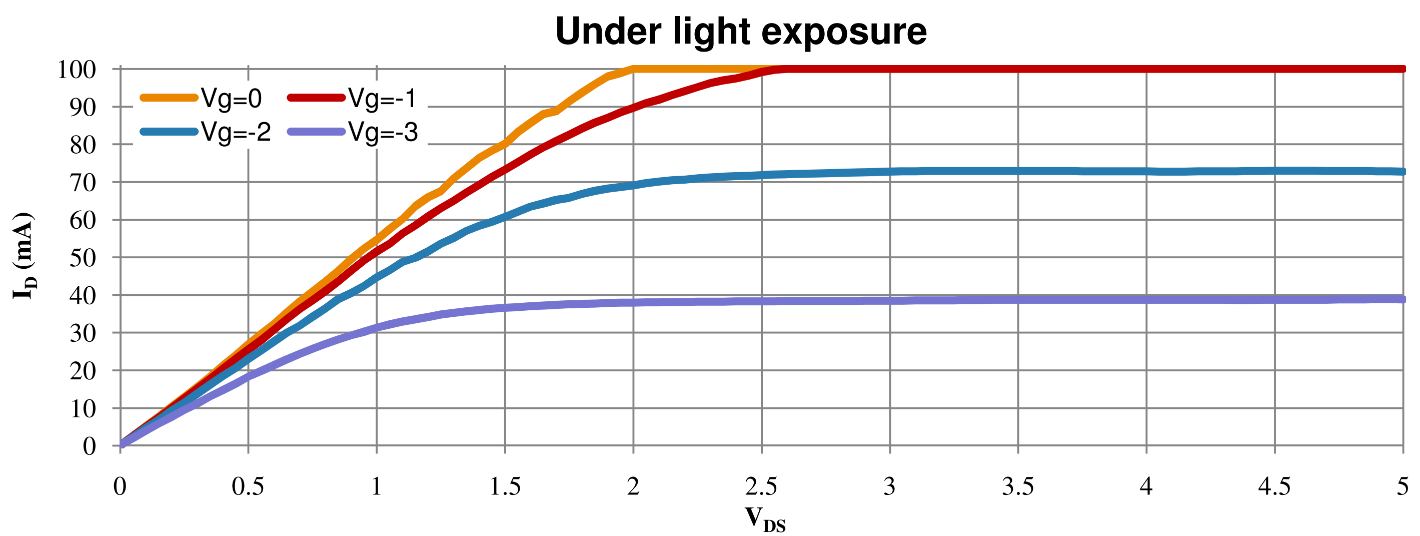
PROOF-OF-CONCEPT

- Probe station and programmable curve tracer
- Proof of concept test
  - Optically pump device
  - Measure device performance while and after exposing
- Compare to unexposed devices
- Device
  - 2003 Vintage GaN HEMT from Sandia Labs
  - Dual gate 0.75 x 100 micron

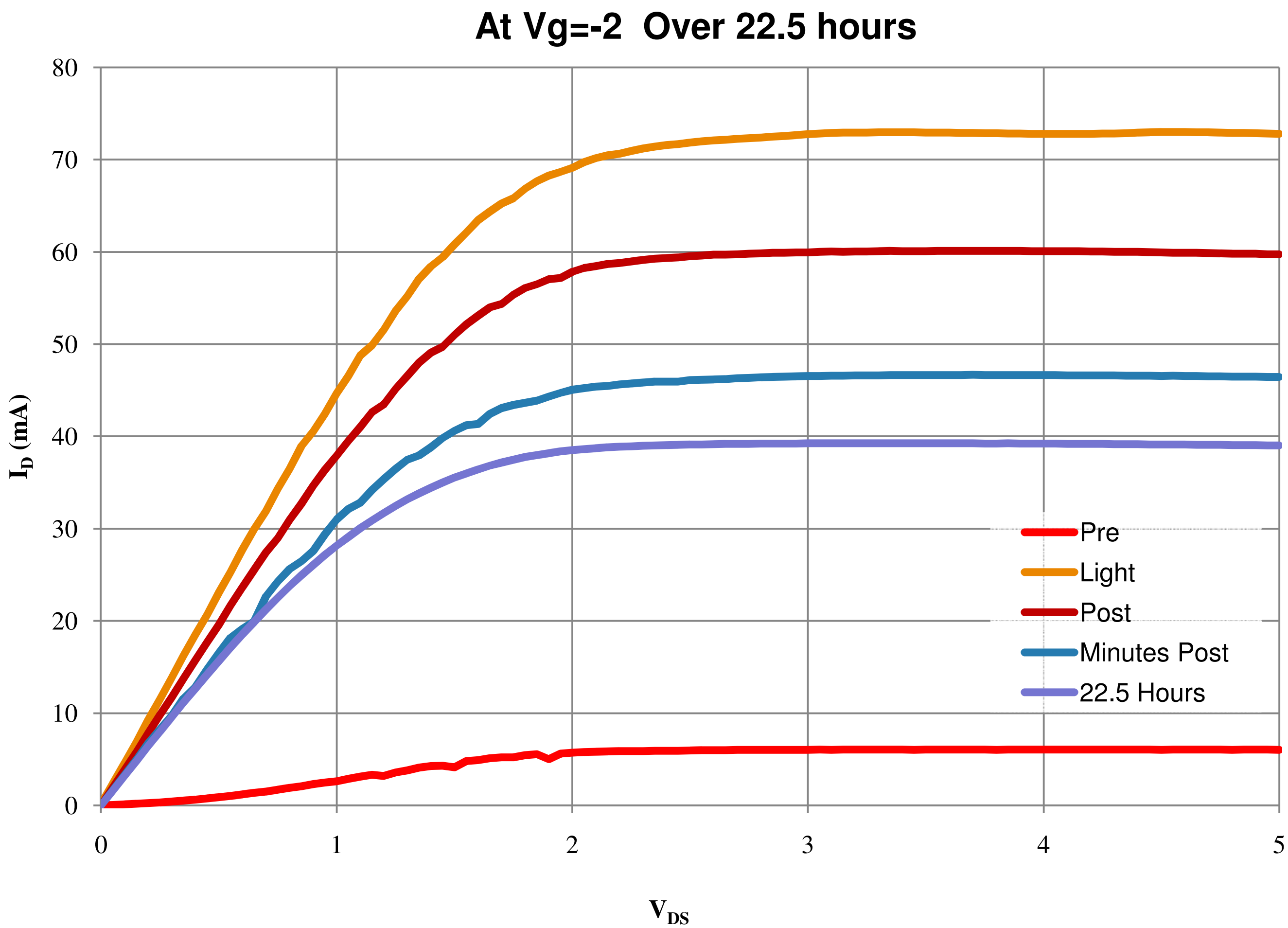


PROOF-OF-CONCEPT RESULTS





RESULTS – OPTICAL PUMPING



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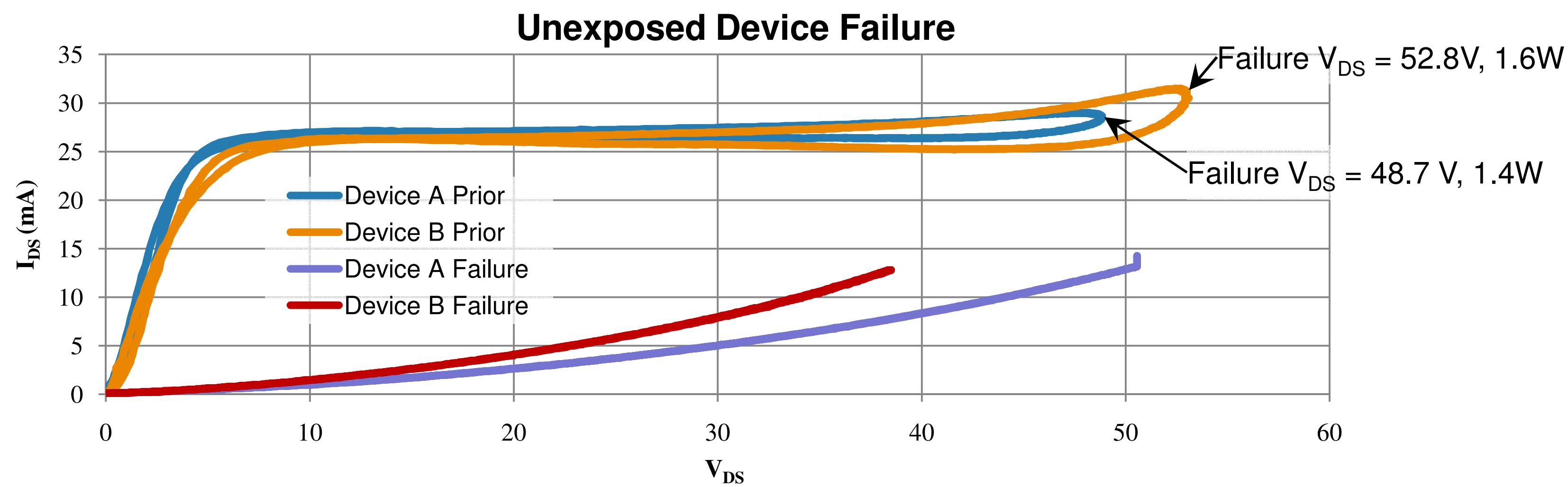
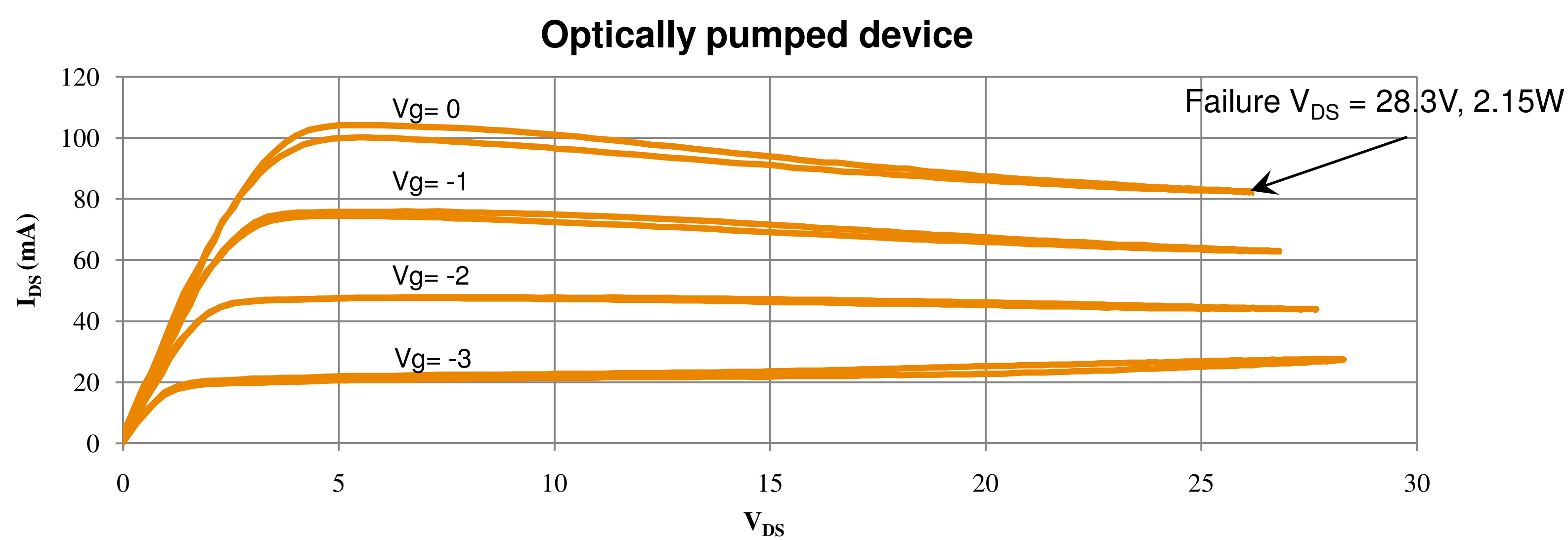
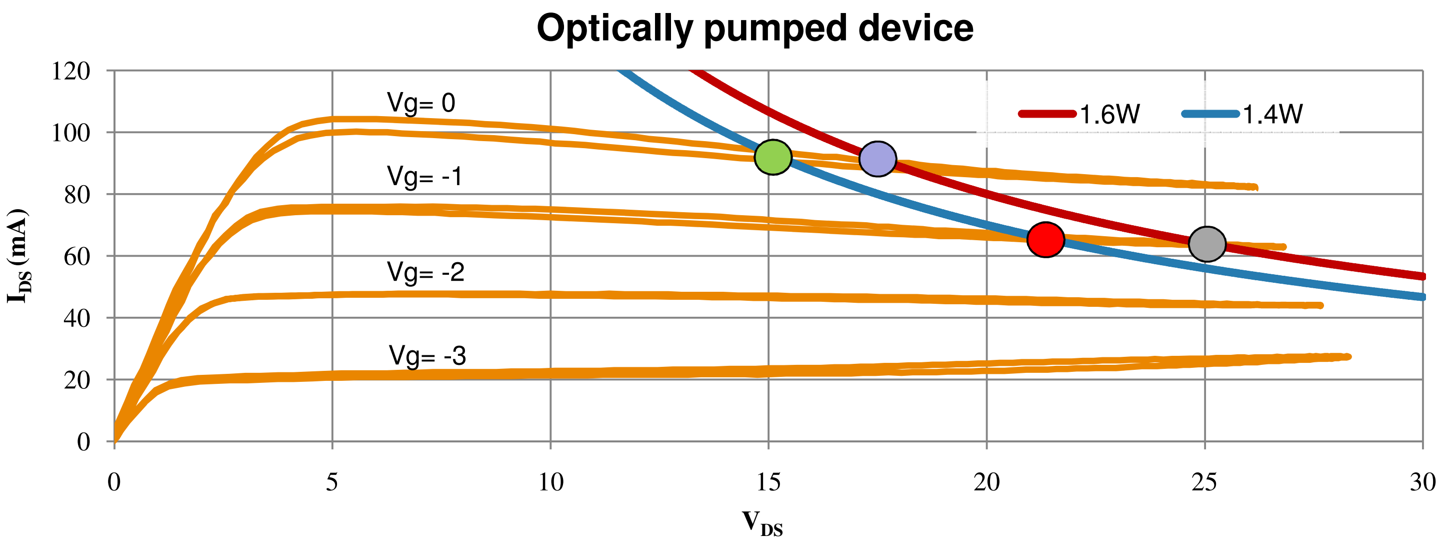
To Failure - Results





FAILURE RESULTS – COMPARISON



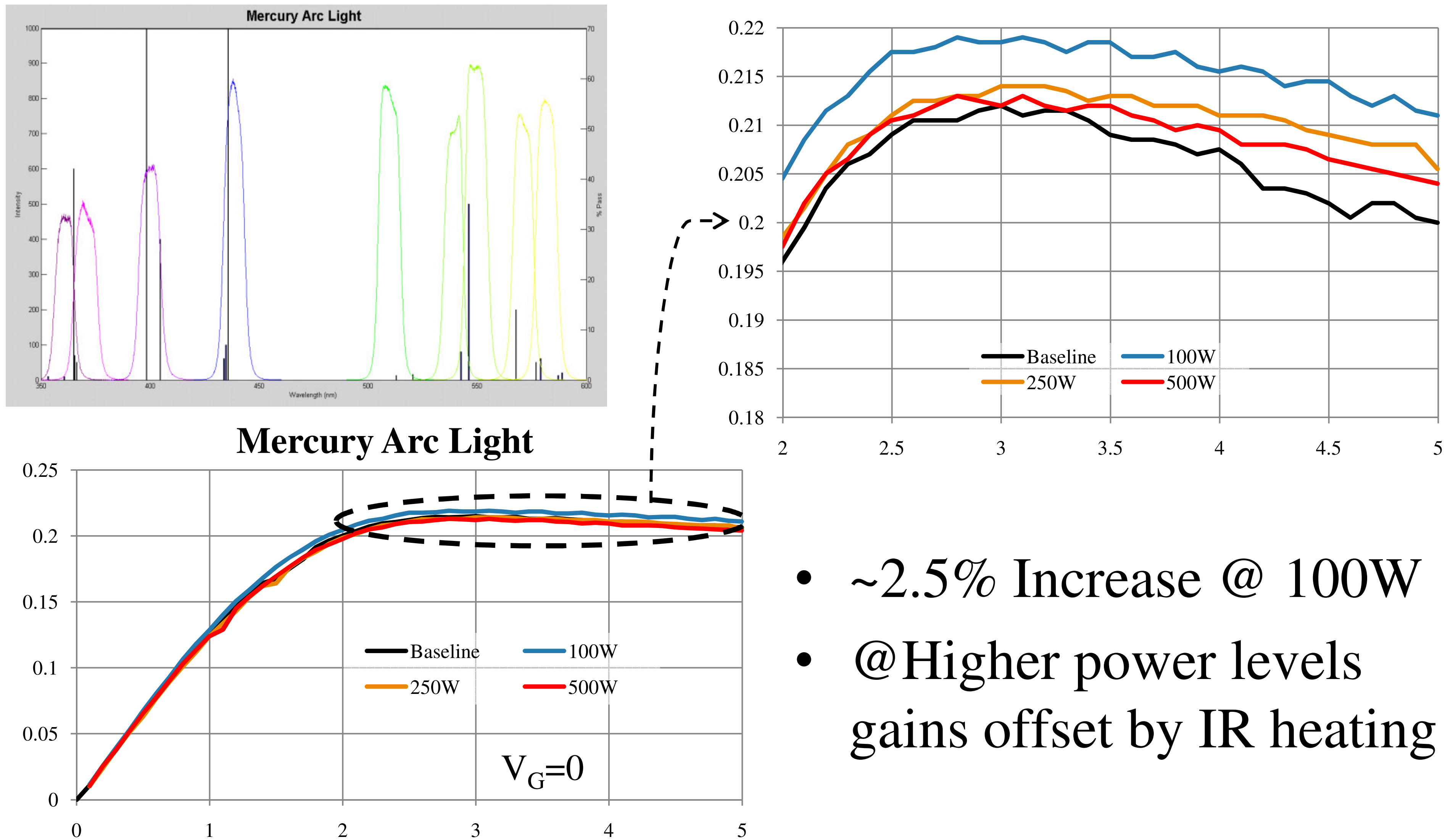
Device A Failure Conditions 52.8V, 1.6W

V_G (0V)	V_{DS} (~53V)	I_D (~30mA)	V_{GD}(~53V)
0V	~17.25V	~93mA	~17.25V
-1V	~24.5V	~65.3mA	~25.5V

Device B Failure Conditions 48.7V, 1.4W

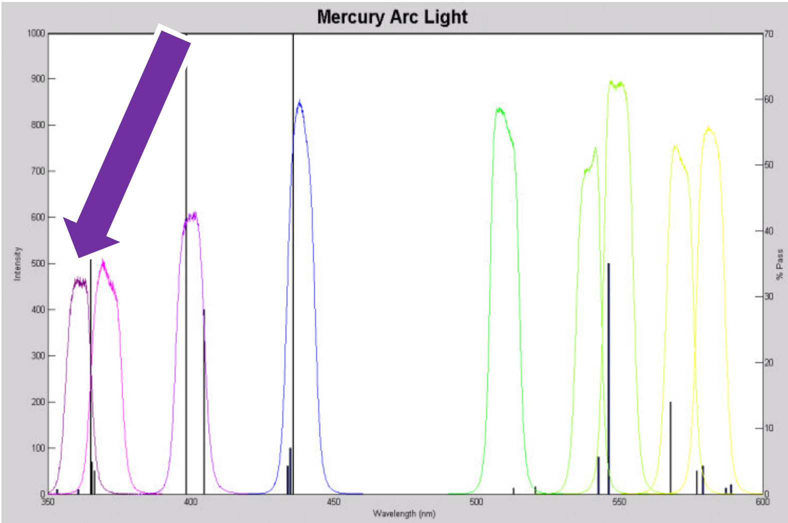
V_G (0V)	V_{DS} (~48.7V)	I_D (~28.9mA)	V_{GD}(~48.5V)
0V	~15V	~93.33mA	~15V
-1V	~20.75V	~67.5mA	~21.75V

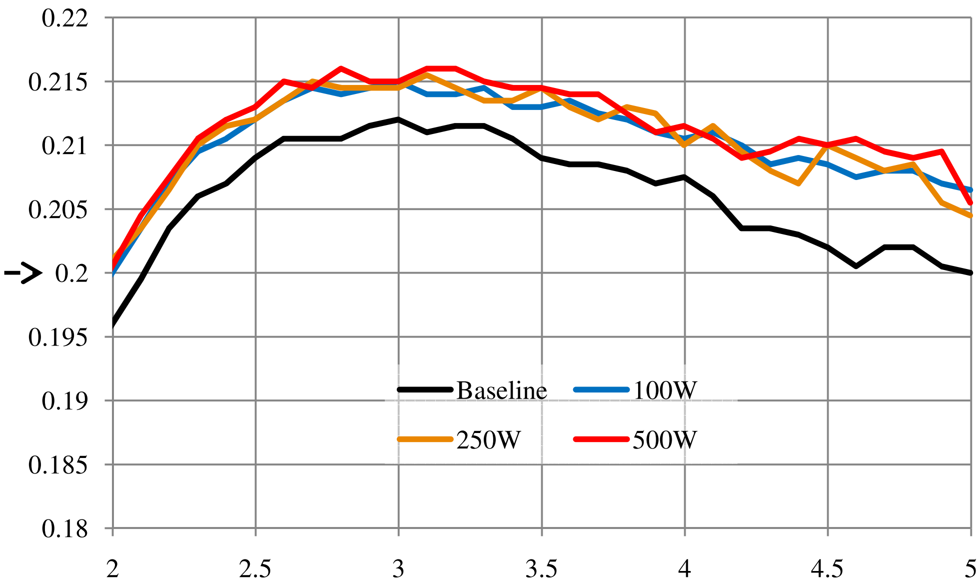
AFRL Parts



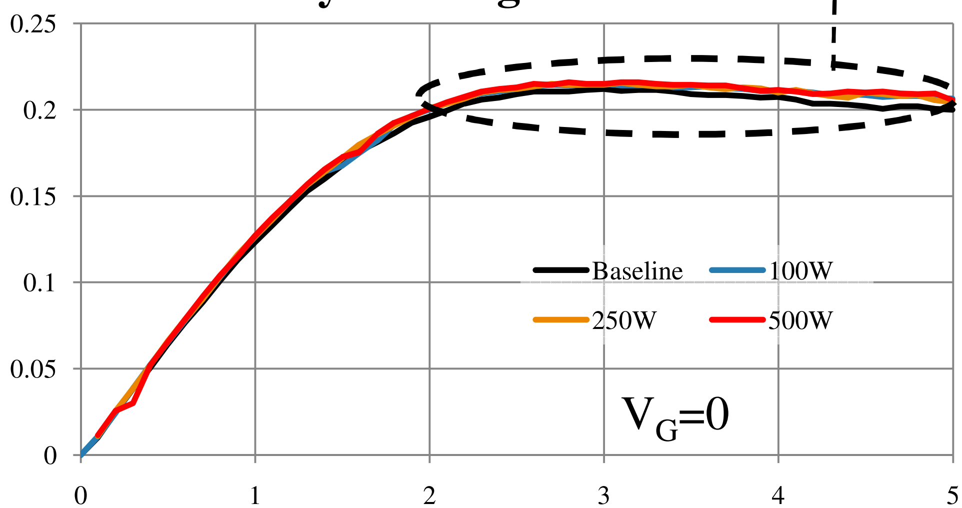
- ~2.5% Increase @ 100W
- @Higher power levels gains offset by IR heating

AFRL Parts



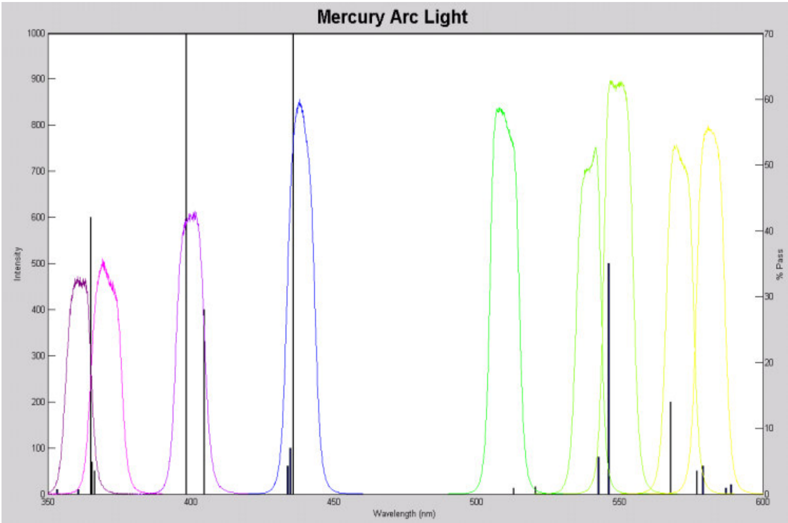


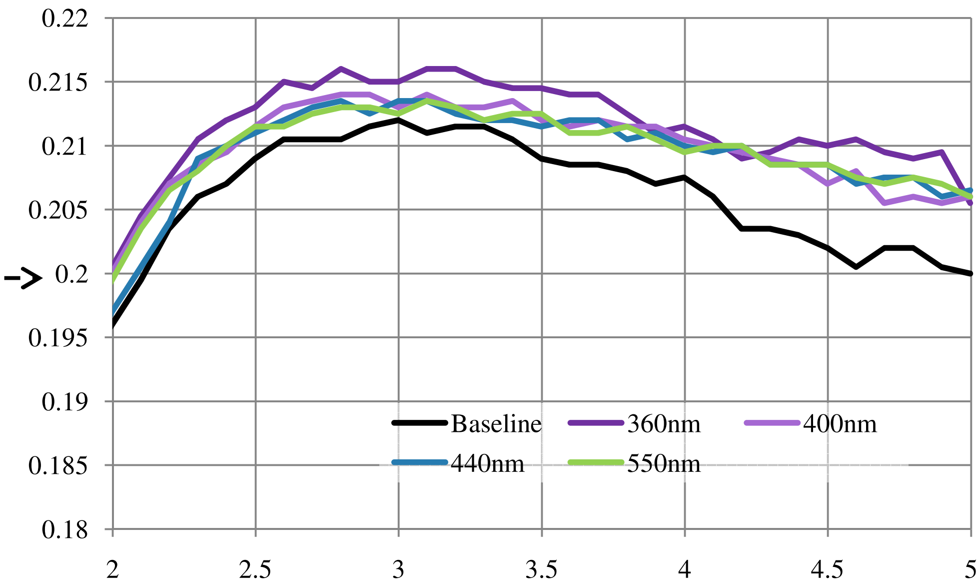
Mercury Arc Light 360nm Filter



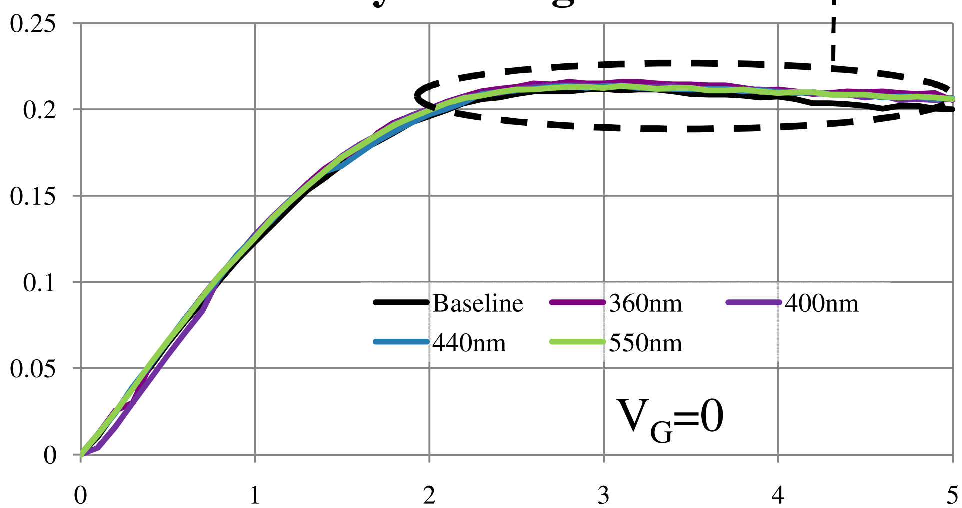
- No IR heating
- Fe Doping?
- Fewer traps?

AFRL Parts





Mercury Arc Light Filtered



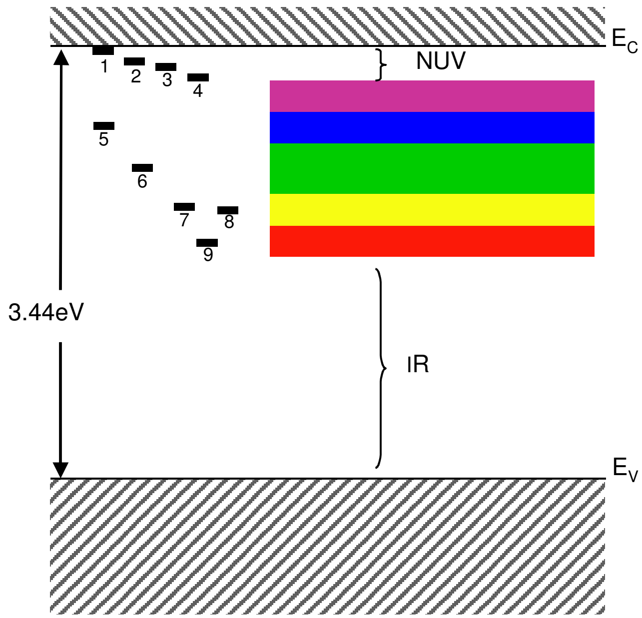
- Shorter wavelength (360nm) clears more traps.

FUTURE WORK

- Light Intensity
- Dependence on device structure, dopants, and passivation.
- Recovery Rate
  - Other factors besides time: dopants, growth processes, and passivation

FUTURE WORK

- Light Wavelength
  - Detection of different line and point defects



Defect	eV	Defect Type
1	3.41	basal plane stacking faults on polar GaN basal plane stacking faults on non-polar GaN a-type threading dislocations
2	3.34	a-plane stacking faults
3	3.28	partial dislocations
4	3.20	C_N
5	2.9	Blue defect - O_N, dopants
6	2.5	Green defect - $V_{Ga}O_N$, dopants
7	2.2	Yellow defect - several vacancy defect models, V_{Ga} bound to dislocation, dopants
8	2.21	edge dislocations (screw dislocations are invisible)
9	1.8	Red defect - V_NC_N, implant damage, dopants

SUMMARY

- Proof-of-concept
  - Optically pumping GaN HEMTs from an unfiltered mercury arc lamp
  - An order of magnitude increase in the drain current
- To Failure Comparison to Unexposed Devices
  - 3x I_D at 1/3 the V_{DS} and V_{DG}
- AFRL Parts
  - 2.5% I_D Increase
  - Fewer traps?
  - Fe Doping?